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A NEW SYSTEM OF COTTON CULTURE AND ITS APPLICATION.[1]

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INTRODUCTION.

The way to secure an early short-season crop of cotton is to thin the plants later and leave them closer together in the rows than is now customary. Neither of these policies is advisable if used alone, but they give a real advantage when properly combined. Keeping the plants closer together during the early stages of growth restricts the formation of vegetative branches and induces an earlier development of fruiting branches. The new system is based on the principle of controlling the formation of the branches.

CONTROLLING THE FORMATION OF BRANCHES.

The principle of branch control is more likely to be understood if studied as the basis of a new cultural system. Application of the principle will involve a reconsideration of all current opinions regarding such questions as distances between rows, times of planting, methods of cultivation, and the values of different varieties. The spacing of the plants and the stages at which thinning should be done will depend upon the local conditions and the habits of the varieties that are being grown, so that it will not be possible to give specific directions that can be used everywhere without discrimination. In agriculture, as in other arts, every new application of a scientific principle makes an additional demand for intelligence and insight into the problems of production. The contrasts with prevalent theories and practices of cotton culture are so great that careful consideration of the habits of the cotton plant is needed before the full possibilities of cultural improvement can be appreciated.

[1] The descriptive portion of this bulletin (pp. 1–5) is to a large extent reprinted from a paper in Bureau of Plant Industry Circular 115, A New System of Cotton Culture, by O. F. Cook, issued Mar. 1, 1913, which is now out of print.

The first step toward permanent progress in the new direction is to secure the attention of the intelligent farmer to the principle itself, so that he can begin to observe and experiment on his own account with rows of cotton thinned to different distances and at different stages of growth and thus see for himself the relation of the habits of the plants to the cultural problems. In this case no special equipment of books or instruments is necessary to enable the farmer to study the plant and learn what he needs to know regarding its habits of branching. It is true that these habits are somewhat peculiar from the botanical and biological standpoint, as already pointed out in preceding papers on the subject, but there are no technicalities that interfere in any way with direct observations of the behavior of the plants under the usual farm conditions.

APPLICATION OF IMPROVED METHODS.

Unless the farmer can understand the underlying reasons, he is not likely to adopt a new method or to apply it properly, any more than he can use a new machine to advantage without knowing how it works. This requirement of intelligence may limit the application of an improved method, just as it restricts the use of high-grade machines to those who have the ability to handle them properly and understand their construction. But it is generally agreed that larger rewards for more intelligent and skillful farming are in the interest of agricultural progress, and this is especially true in relation to the cotton industry. To make it seem worth while for intelligent men to remain on the farm would soon counteract the urban tendencies now so much deplored.

That cotton has been considered a "sure crop," even with the most careless farming, is one of the chief reasons for the backward state of the industry. But the need of improvement is now recognized as never before, as a result of the many changes that are being enforced by the invasion of the boll weevil. With the continued advance of the boll weevil the period of sure-crop cotton is drawing to a close, and the rapid expansion of cotton culture in foreign countries shows that a new test of competition in the production of this crop must be met in a few years. In the meantime any improvement that promises increased efficiency of production is worthy of careful consideration.

IMPORTANCE OF STIMULATING EARLINESS.

The chief advantage of the new system of cotton culture, based on the improved method of thinning, is the increased earliness of the crop; or, in other words, the production of more cotton in a shorter period of time. The need of shortening the growing season of cotton has been recognized as the best solution of the problem of secur-

ing protection against injury from the boll weevil, but is no less important in regions where the crop is limited by drought or by short seasons, as in the northern districts of the cotton belt.

CONFLICTING OPINIONS ON SPACING COTTON ROWS.

Many intelligent farmers are aware of the fact that rows of cotton accidentally left without thinning are sometimes much more productive than rows that were thinned in the usual manner and have reflected on the possibility of securing larger crops by closer planting, but the underlying biological principle has not been understood. The behavior of cotton in different seasons or under different conditions is so extremely variable that any intelligent farmer might well hesitate to adopt a method of culture suggested by an occasional occurrence like the production of a larger crop on an unthinned row.

In each cotton-growing community there are usually some farmers who believe that cotton should be left closer together in the rows, but the tendency in recent years has been toward wider spacing, owing to a general recognition of the evil effects of having the plants too close together, especially under conditions that favor luxuriant growth. Those who use narrow spacing may boast of phenomenal yields in some seasons, but in other years they appear at a disadvantage with their neighbors. The possibility of making a safe combination of the two conflicting methods seems not to have been suggested. The same conflict is shown in the results of formal experiments to determine the best planting distances as in the popular opinions on the subject. Wide spacing in the rows seemed better in some cases and narrow spacing in others, so that no definite conclusions could be reached.

LARGE PLANTS PRODUCE LATE CROPS.

When the habits of the cotton plant are taken into account it becomes apparent that the theory of wider planting has its limitations, as well as the theory of closer planting. To reduce the number of plants by wider spacing in the rows means that a longer period of time is required to produce a crop, for the reason that large luxuriant plants do not begin to produce flowers and bolls as early as plants of more restricted growth. This is not in accord with what might be considered as the most logical view of the subject. Most people are ready to argue that the plants making the most rapid growth must produce the earliest and largest crop, but the actual behavior of the cotton plant is otherwise. In such cases the biological facts have to be taken into account instead of relying upon the logical deductions.

The biological fact in the present case is that the large luxuriant plants are later in setting and maturing a crop. This is because the

young plants in a condition of luxuriant growth develop vegetative limbs at the expense of the lower fruiting branches that are necessary to the production of an early crop. The cotton plant has two different kinds of branches—vegetative branches, sometimes called "wood limbs," which correspond to the main stalk of the plant, and fruiting branches, which produce the flowers and bolls.

When the habits of branching are understood it becomes apparent that the idea of the largest plants producing the earliest and largest crops does not apply to cotton. Spreading, treelike plants, with numerous vegetative branches, do not represent a favorable condition for earliness or for large yields in short seasons. In the interest of correct thinking on cultural problems the row rather than the individual plant should be considered as the unit. The advantages of the new method are gained by improving the form of the rows. More plants are left in the rows, and yet injurious crowding is avoided. Plants that have numerous vegetative branches are more crowded at 2 or 3 feet than plants with single stalks at 8 or 10 inches. With the vegetative branches controlled, the spacing is no longer a question of feet, but of inches. Rows spaced at 6 inches have usually given better results than those at 12 inches or any greater distance.

EXPOSURE OF FRUITING BRANCHES TO LIGHT.

By avoiding the development of the large wood limbs the rows are kept narrower and more hedgelike, so that the fruiting branches receive sunlight throughout the season. This provides much more favorable conditions for the ripening of the crop. When the vegetative branches are allowed to shut off the light by growing up between the rows, most of the bolls on the lower fruiting branches fail to reach normal maturity. Fields of large luxuriant plants often produce very small crops because only the upright growing ends of the stalks and vegetative branches have access to the light. This undesirable condition is avoided by restricting the development of the vegetative branches in the earlier stages of growth.

Numerous experiments have demonstrated the fact that the usual custom of giving the seedlings full exposure by thinning them to wide distances in the rows is a means of inducing the development of large numbers of vegetative limbs. Too much exposure for the young plants results in too little exposure for the adults by increasing the number of vegetative branches. The effect of exposure at wide distances is influenced, of course, by temperature and fertility of soil, larger numbers of vegetative limbs being produced under conditions that favor the luxuriant growth of the plants. But it does not appear that the production of vegetative branches is desirable under any condition. The improved method of thinning restricts the development of vegetative limbs or avoids their formation alto-

gether. This permits a better development of the fruiting branches of the lower part of the main stalk. The plants are induced to fruit earlier and the crop is made larger because more of the early plants can be grown on the same area.

COMPETITION BETWEEN TWO KINDS OF BRANCHES.

The reason this possibility of cultural improvement has not received adequate consideration in the past is doubtless to be found in the fact that the distinctness of the two kinds of branches has not been recognized, nor the relation of this specialization to the method of thinning. When the plants are thinned too young, so as to stand more than 6 inches apart, they put forth a full quota of vegetative limbs, and the subsequent competition and crowding of these limbs with each other and with the main stalks interfere with the development of normal fruiting branches. As it is the low joints of the stalk that produce the undersirable vegetative branches, the plants must be allowed to grow beyond these joints before thinning. Exposure of the stalk to the light in the early stages of growth is one of the factors that lead to the putting forth of the vegetative branches.

EFFECTS OF EXTERNAL CONDITIONS ON BRANCH FORMATION.

The number of vegetative branches is also influenced by temperature and soil conditions. If the weather remains cool, or if the soil is very dry, not many vegetative branches will develop, even when the young plants are widely separated. But if the conditions favor a luxuriant development of the young plants, early thinning will result in the development of a large number of vegetative branches, and the subsequent crowding will be great. Even in the absence of any disease or insect pests the crop may be ruined by crowding alone. Thus, the extent of the injury from crowding depends very largely on the conditions that obtain during the early development of the plant when the formation of vegetative branches is determined.

Until the habits of the branching are taken into account, it seems impossible to explain the widely different results that are often secured when the same experiments are repeated in different places or in the same place in different seasons. From the present point of view, it is easy to understand that merely statistical experiments made without recognizing the effects of different methods of thinning upon the formation of branches would be likely to reach only ambiguous results. The development of the branches, though very easily influenced in the early stages of growth, completely alters the subsequent behavior of the plants. The effect seems out of all proportion to the exciting cause, like touching off a charge of powder or pulling the trigger of a gun.

Wider spacing appears as the only alternative as long as the young plants are led to put forth a full equipment of vegetative limbs by too much exposure in the early stages of growth. That the development of these limbs may be avoided by a later and more gradual thinning of the young plants must be recognized before it is possible to understand the advantages of the new system. When good crops are produced on rows that are not thinned at all, it is because the plants remain so close together that no vegetative limbs are developed. The new system provides for a more regular and effective application of the same principle of suppression of vegetative branches.

WHY FARMERS ARE ADVISED TO TRY THINNING EXPERIMENTS.

Farmers are advised to experiment with the new system in order to learn how to use it. The experiments that have been made by the Department of Agriculture leave no doubt of the practical advantages that are to be gained by suppressing the vegetative branches, but it is not expected that the farmer will secure a practical familiarity with the system merely by reading about the experiments that others have made.

How long the thinning should be delayed to suppress the vegetative branches and how close the plants should be left in the rows are questions that the skillful farmer should learn to determine for himself, since the actual conditions must be taken into account to secure the best results. If the farmer does not look into the subject far enough to grasp the underlying principle, he is not likely to be able to appreciate the new method or to use it to the best advantage. Hence no explicit directions were issued when the new system was announced, but farmers were advised to study the matter for themselves and to make experiments with a few rows of cotton in order to see that they really understand the principle and to make sure that they are able to secure an advantage from it before attempting to apply it to their whole crop.

The two features of the new system—deferred thinning and closer spacing—must be properly combined in order to insure a favorable result. Most farmers believe that either of these changes will injure the crop, and the danger is that they will try one change without the other instead of making a complete break with previous theories and methods. Until the principle of branch control is understood it is difficult to believe that two apparently injurious changes can have a beneficial result. Attention must be called to the peculiar structure and habits of the cotton plant, in order to place in the hands of the farmer this new power of controlling the development of his crop. The introduction and general utilization of the new system is hardly to be expected without a campaign of education. Not many farmers will be able to believe the new doctrine, and still fewer will apply it

successfully, merely from reading or hearing about it. They must be induced to try the experiment for themselves, and to encourage this tendency nothing is so good as an example. Hence, it is believed that the following letter from one of the cooperators of the Department of Agriculture in South Carolina will be of interest:

EASLEY, S. C., *February 14, 1914.*

Mr. O. F. COOK, *Washington, D. C.*

DEAR MR. COOK: Perhaps you may remember that in the very late patch of Columbia one row was left thick. I carefully gathered and weighed that row, as I also did the row on either side. The result was as follows:

Number and length of row.	Number of plants.	First picking.	Second picking.	Total yield.	Yield per acre.	Proportion of lint.[1]	Length of staple.[1]
		Pounds.	*Pounds.*	*Pounds.*	*Pounds*	*Per cent.*	*Inches.*
1. 335 feet	118	16	9	25	655	30.0	1 1/16
2. 352 feet	294	28	13½	41½	1,020.9	31.0	1 1/16
3. 359 feet	119	20	12½	32½	793	29.5	1 1/16

[1] These figures were added at Washington, on the basis of the samples furnished by Mr. Carpenter. It will be observed that the rows reported in Mr. Carpenter's letter are of unequal length, which makes it somewhat difficult to compare the results. On a basis of computation for rows of a uniform length of 300 feet, the yields of the three rows would have been 22.37 pounds, 35.31 pounds, and 27.20 pounds, respectively.

About one-third were cut off by frost.

The increased yield of the third row over the first row was probably due in a large measure to the fact that this row was within 10 feet of the terrace and the soil is therefore deeper. Recognizing this inequality caused me to take the row on either side for comparison with our crowded row.

However, I would not trespass on your time with these results—for they have already been established by your Norfolk experiment—had I not wished you to assist me one step more. I especially desire to know if there is any effect on the lint, and, if so, in what way. Possibly you may have made this investigation. If so, I would appreciate receiving the bulletin containing the results.

But as you may not have made the inquiry, I have mailed to-day to Mr. Anders a sample of seed cotton from each of these three rows, hoping that with the appliances that doubtless your office has he may be able to throw some light on this, to the producer, most interesting question.

Yours truly, C. H. CARPENTER.

RESULTS OF OTHER EXPERIMENTS.

The results secured by Mr. Carpenter are, as he recognized, in substantial accord with those obtained in experiments with the new method of thinning at Norfolk, Va., in the season of 1912, as published in Circular No. 115 of the Bureau of Plant Industry. In Mr. Carpenter's experiment the close-spaced row exceeded one of the open rows by 57.8 per cent and the other by 29.8 per cent. At Norfolk in 1912 the average gain of 7 close rows compared with 7 open rows was 53 per cent. In a similar experiment in 1913, in which 37 rows were compared with 37 open rows, the average gain of the close rows over the open rows was 35 per cent in the first picking and 26 per cent in the total crop. Figure 1 affords a graphic illustration of the behavior of the close and open rows of the experiment of 1912

and an equal number of rows of the experiment of 1913. These experiments were made with the Durango cotton, instead of with the Columbia, and the plants were left much closer in the rows than in Mr. Carpenter's experiment.

Of course, it is not to be expected that all experiments will show such striking advantages for the close-spaced rows. The desirability of suppressing the vegetative branches was first recognized in experiments with Egyptian cotton in Arizona and southern California, though the actual differences in yield have been less striking under the conditions in the Southwest, because the seasons are longer. With sufficiently long seasons and ideal conditions in other respects, the open rows might equal the close rows, but most seasons are not ideal, and it is usually a practical advantage to secure an early crop.

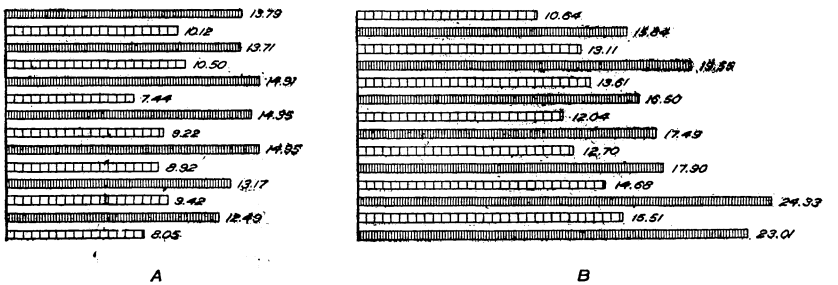

FIG. 1.—Diagrams showing comparative yields of close-spaced and open-spaced rows of Durango cotton, each row representing 0.01 of an acre. *A*, Grown at the Virginia Truck Experiment Station at Diamond Springs, Va., in 1912; *B*, grown at Deep Creek, Va., in 1913.

Under weevil conditions earliness is recognized as a matter of primary importance, for insects are often able to prevent the setting of any bolls in the latter part of the season.

NO ADVERSE EFFECT ON THE LINT.

In answering Mr. Carpenter's question regarding the effect of closer spacing on the length of the lint, the samples received by Mr. Anders were carefully compared by combing out the lint of individual seeds and mounting them in parallel series and the ginned fiber was submitted to an expert classer, Mr. D. E. Earle. In neither of these examinations was it possible to detect any indication of an adverse effect due to the closer spacing. The position of the rows on the terrace seemed to have had more influence than the distance between the plants in the rows. The lint of the outside row was slightly longer than that of the inside row, with the close-spaced row strictly intermediate and not at all inferior in strength or drag to the others, but, if anything, slightly better, in the opinion of Mr. Earle.

It would not appear unreasonable to suppose that there might be at least a very slight shortening of the lint as a result of closer planting, for it has been observed in some experiments that the bolls of

the close-spaced rows averaged somewhat smaller and that a larger percentage of the bolls had only four locks. But it seems likely that any slight difference that may exist in the length of the lint will be more than made good by the greater uniformity. Large overgrown plants often yield very irregular lint, because they are much more likely to be checked severely by unfavorable conditions. It has been noticed in some of the experiments that when the large plants in the open rows become wilted in the middle of the day, the smaller plants in the close rows remain fresh. An effect of this kind may be responsible for the different lint percentages found in the samples sent by Mr. Carpenter. The samples were divided, so that two independent determinations of the percentage could be made in each case, but the results were the same.

SUGGESTIONS FOR FURTHER EXPERIMENTS.

As Mr. Carpenter's letter shows, the experiment was a very simple one that any farmer could make for himself if sufficiently interested in learning how to use the new system. More accurate comparisons can be made, of course, if the new system is applied to several rows or small blocks alternating with others thinned in the usual way, but even a single row may serve to demonstrate the principal effects of the improved method, the suppression of the vegetative branches and the increased earliness of the crop. No special precautions are necessary in the planting or cultivation of the rows that are to be thinned in the new way, except to keep them from being chopped out too early with the rest of the field. If general advice were to be given, 8 or 9 inches might be suggested as a safe distance, but under some conditions closer spacing may be better. In experiments with Egyptian cotton in Arizona, rows spaced to 3 inches have given the highest yield at the first picking.

In many cases all that is necessary is to leave the experimental rows without chopping until the plants are 8 or 10 inches high and then thin out to 8 or 10 inches apart in the rows. A still safer course is to thin to 2 or 3 inches when the plants are 8 or 10 inches high and to make the final thinning when the plants are 12 to 15 inches high. For the final thinning, any distance from 6 to 12 inches in the row is likely to give better results than a greater distance, if the thinning is done at the right time.

It will be found interesting to vary the time of thinning as well as the spacing in the row. Under some conditions it may be desirable to leave the plants till they are 12 or even 15 inches tall before thinning and then pull out only a few of them. One advantage of leaving several rows to be thinned by the new method is that different distances can be tried, so that the farmer who studies his experiment can form his own judgment regarding the best distance for the variety and the local conditions. Thinning too early allows too many of

the vegetative branches to start, so that the object of suppressing these branches is only partially accomplished. In cool seasons or under conditions that do not favor the rapid, luxuriant growth of the young plants somewhat earlier thinning may be advisable, for under such conditions there is less danger of producing vegetative branches. With this danger avoided it is desirable to allow the fruiting branches to develop as rapidly as possible. Some varieties have less tendency to produce vegetative branches, and it may be that such varieties can be thinned somewhat earlier without losing the advantage of suppressing the vegetative branches. But there is seldom, if ever, any advantage in having the young plants stand wide apart. Usually they grow much more rapidly when allowed to remain close together during the seedling stage.

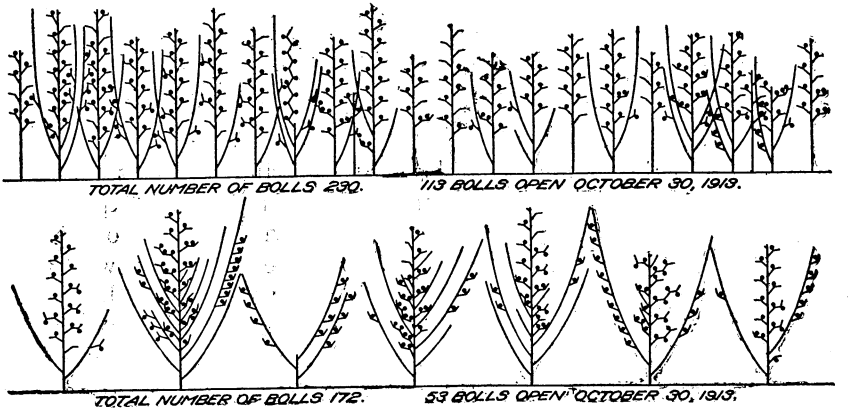

FIG. 2.—Diagrams of plants growing in 15 feet of adjacent open-spaced and close-spaced rows of Durango cotton at Deep Creek, near Norfolk, Va. These are portions of two of the rows represented in the diagram shown at *B* in figure 1.

If the stand is very thick, so that the seedlings stand on the average less than 1 or 2 inches apart in the row, a slightly early thinning or chopping may be advisable, to open up the thickest places where the young plants may become too spindling, but not enough plants should be taken out to break the continuous hedge formation of the row. The exposure of the stalks of the young plants to the sunlight seems to be one of the exciting causes that induce the development of vegetative branches. Young plants that stand 6 inches or more from their neighbors are likely to put forth full sets of vegetative branches if other conditions are favorable for luxuriant growth. Hence, the plants must be kept less than 6 inches apart in the early stages if suppression of the branches is to be insured. The nature of the effect produced by keeping the plants closer together in the rows may be understood by reference to figure 2, which shows a diagram prepared by Mr. G. S. Meloy from actual counts of bolls and measurements of the main stalks and vegetative branches of plants growing in adjacent rows in an experiment with Durango cotton near Norfolk, Va.,

in the season of 1913. The distances between the plants, the height of the main stalks, and the length of the vegetative branches are drawn to the same scale. It will be seen that development of the vegetative branches has been restricted greatly in the close-spaced row and that most of the bolls are produced on fruiting branches of the main stalks instead of on the vegetative branches. On October 30 there were 53 open bolls on the open-spaced plants as compared with 113 open bolls in the same distance in the adjacent close-spaced row.

Where the stand is poor, so that the average distance between the plants is 3 or 4 inches and the conditions do not favor luxuriant growth, some of the rows may be left without any thinning, and these are likely to be earlier and more productive than those that are thinned. This will afford still more striking evidence of the fact that the present method of thinning early to wide distances often reduces the yield. When thinning is deferred, the farmer can handle his crop in closer accord with the actual conditions of growth.

INCIDENTAL ADVANTAGES OF CLOSER SPACING.

Leaving the plants close together in the earlier stages is distinctly beneficial on account of the mutual protection against exposure to heat and cold, and especially against the wind, which often kills young seedlings that have been thinned too early. The wind may be directly injurious by breaking, beating, or shriveling the plants, and indirectly by blowing sand against the young stalks until they are wounded or actually cut off.

Exposure is also responsible for extensive injuries to young seedlings by the leaf-cut disorder. This is often confused with the leaf curl caused by plant lice, but in reality is entirely distinct. Leaving the young plants closer together is a means of reducing leaf-cut injury and of shortening the period of susceptibility.[1]

The exposure of the seedlings to such dangers is increased when cotton is planted very early. Many farmers prefer to plant early, especially in Texas and other Southwestern States, because they have noticed that late-planted cotton "grows more weed"; that is, the plants are too luxuriant and have too many vegetative branches. But with a practical method of controlling the formation of the branches there is less reason for taking the other risks of very early planting.

Another advantage of later thinning is that the weak and deformed or otherwise abnormal plants are easily recognized and pulled out, leaving the best individuals to produce the crop. Preserving the continuous hedge formation of the rows also keeps the weeds from springing up between the plants and close along the rows, so that not so much hand labor is required in weeding and hoeing. The

[1] Cook, O. F. Leaf cut, or tomosis, a disorder of cotton seedlings. U. S. Department of Agriculture, Bureau of Plant Industry, Circular 120, 1913.

more upright form of the plants leaves more open space between the rows and permits horse cultivation to be continued later in the season. The foliage is not so close to the ground, and there are more chances that fallen buds or "squares" containing weevil larvæ will be reached and dried out by the sun than when the plants are allowed to send out long branches from the base of the stalk. If open-spaced plants are at all luxuriant, the lower branches are likely to become prostrate, so that the ground is completely covered.

Thus, it becomes apparent that many cultural operations and factors of production are likely to be affected by the application of the principle of branch control. This is the reason why it seemed best to announce the application of the principle of controlling the formation of the branches as a new system of cotton culture rather than as an improved method of thinning. The suppression of the vegetative branches by later and more gradual thinning is a radical departure from the present system and opens the way to many other improvements of cultural methods.

CONCLUSIONS.

The new system of cotton culture is based on the application of a principle not hitherto recognized in cultural experiments—the control of the vegetative branches by improved methods of thinning. The formation of vegetative branches can be controlled by leaving the plants closer together during the early stages, until the stalks have grown beyond the stage where vegetative branches are produced.

The essential feature of the new system is later or more gradual thinning. This makes it possible to leave more plants in the rows than is now customary, and yet injurious crowding is avoided through suppression of the vegetative branches.

The control or suppression of the vegetative branches also permits an earlier development of fruiting branches and leads to the production of an earlier crop. In regions where the period of crop production is limited, either by short seasons or by the presence of the boll weevil, increased earliness is a means of securing larger yields.

When the incidental advantages are understood and added to the chief consideration of increased earliness and larger yields in short seasons, the prospect of usefulness for the new system appears very large. It is especially adapted to weevil conditions, for there the problem of short-season production is most acute. No other way has been suggested whereby it is possible for the farmer to gain such direct control of the behavior of his crop. The danger of weevil injury is greatest under conditions that favor the luxuriant growth of the young plants and induce the formation of large numbers of vegetative branches, and it is under such conditions that the control of the formation of branches becomes most effective as a method of weevil resistance.

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